Multi-Frequency Radar/Passive Microwave Observations and Simulations of Cold Season Precipitation from GPM and OLYMPEX

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Summary

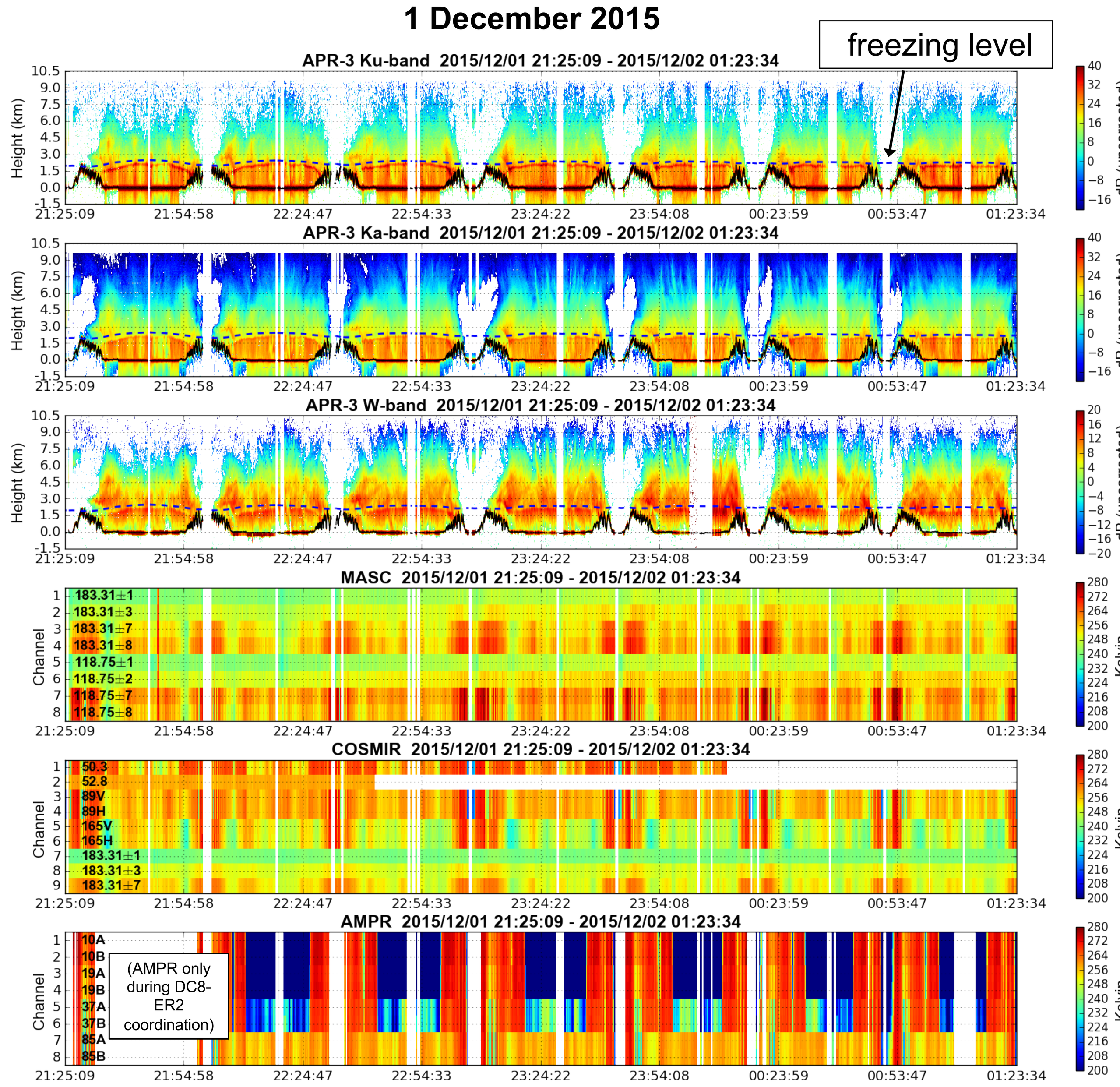
There has been considerable recent activity towards improving the understanding of scattering properties of frozen precipitation at mm-wave frequencies, associated computational methods, scattering/emission tables, and multi-frequency (three frequencies or more) radar measurement concepts. However, there are limited real-world observations to test and evaluate their use for space-based precipitation measurements and techniques. Two datasets have been prepared for these and other studies, such as future space-based cloud process studies, such as the Cloud and Precipitation Processes concept (CAPPM): https://pmm.nasa.gov/cappm. Contact J. Turk (email above) for more information and availability.

Rachel Kroodsma (GSFC), Sharmila Padmanabhan (JPL) and Tim Lang (MSFC) are acknowledged for COSMIR, MASC and AMPR data, respectively.

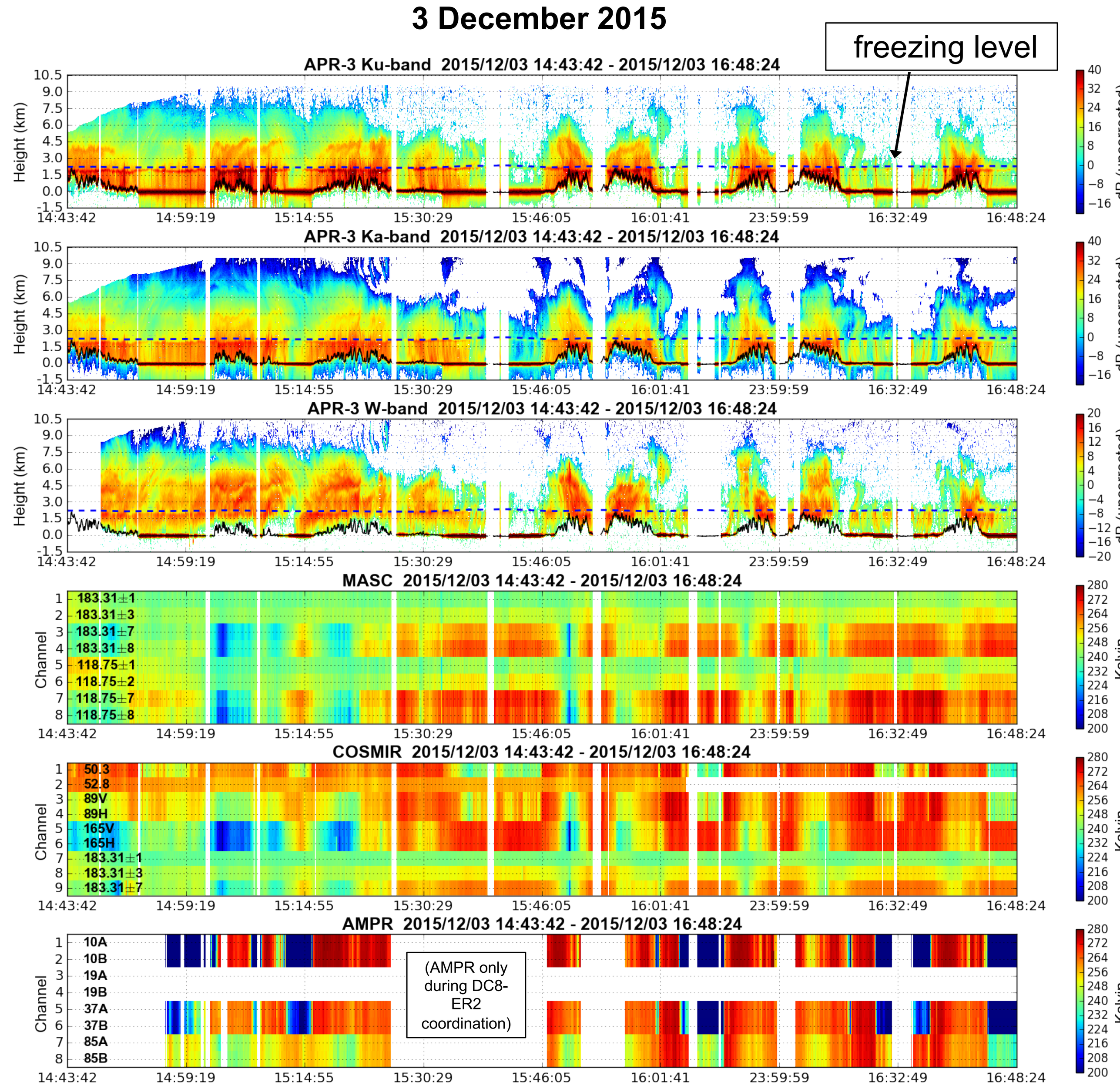
Airborne: OLYMPEx APR-3 + COSMIR + MASC + AMPR + MERRA2

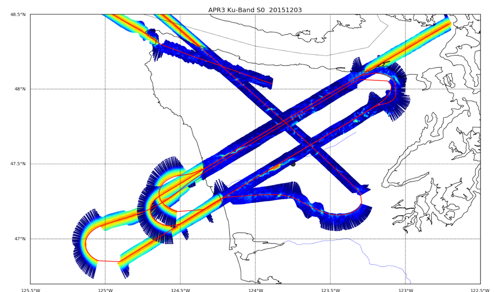
During the Nov-Dec 2015 OLYMPEx campaign, there were fifteen flight dates where the NASA DC-8 collected simultaneous Ku/Ka/W-band APR-3 radar profiles (W-band unavailable 11/14 and 12/8), sounding radiometer observations from the Conically Scanning Millimeter-wave Imaging Radiometer (COSMIR) and the Microwave Atmosphere Sounder on Cubesat (MASC). On many dates, coincident Advanced Microwave Precipitation Radiometer (AMPR) data are available from coordinated ER-2 overpasses. MERRA2 atmosphere and surface reanalysis data was interpolated to each APR3 beam location to provide environmental context.

1 December 2015

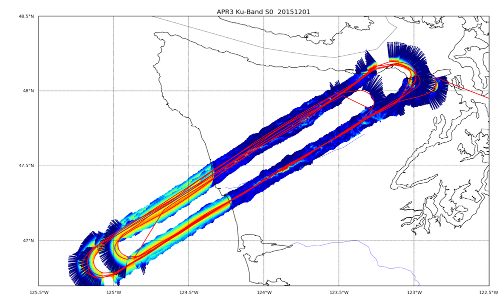


3 December 2015

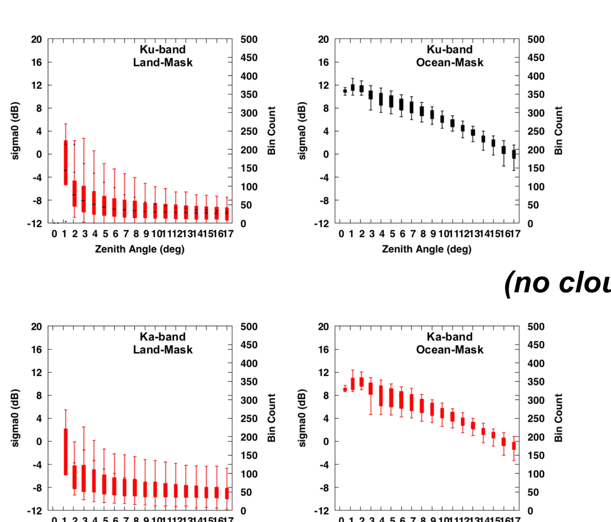




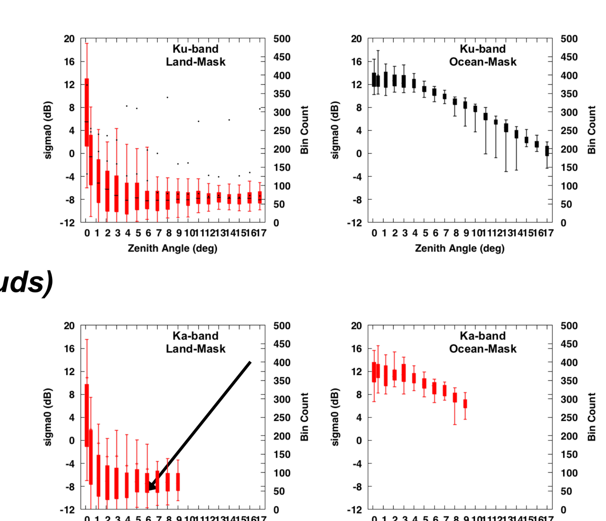
Both the December 1 and 3 DC-8 flight lines were focused on flying up/down the Quinault river basin and that was covered by the NPOL and D3R radars. On December 1, moderately heavy stratiform rain was produced by a baroclinic system, where the structure was modified by the high elevation terrain and gradual change in the freezing level. On December 3, more convective cloud systems were overflown, with evidence in both the 166 and 183±7 channels on COSMIR and MASC.



APR-3 Land/Ocean Ku/Ka σ^0 All Flights



DPR Land/Ocean Ku/Ka σ^0 Nov-Dec 2015 OLYMPEx Region



Box-and-whiskers plots of the APR-3 and corresponding GPM-DPR Ku/Ka-band surface backscattering cross section σ^0 under no-cloud scenes. All DPR overpasses in Nov-Dec 2015 covering the 46.9-48.5N 125.2-122.7W domain (1.5 x 2.5 degree) were used for comparison. The Ku/Ka radars agree within 1-3 dB, without accounting for any resolution differences, or offset time coincidence effects.

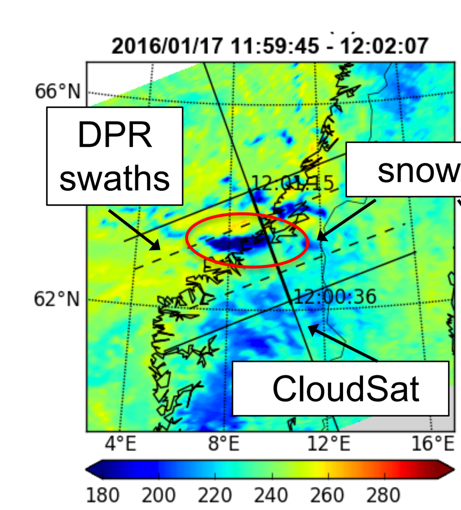
This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Support from the NASA under the Precipitation Measuring Missions (PMM) program is gratefully acknowledged.

Satellite: GPM-DPR/GMI + CloudSat + MHS + ECMWF + (Products)

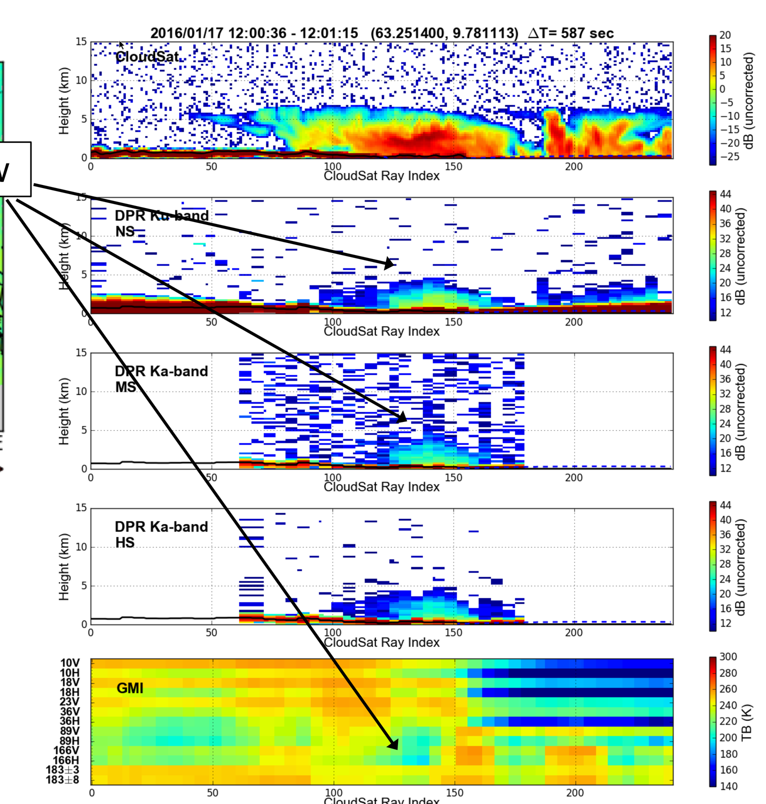
±15-minute time coincidences between GPM and CloudSat (NOAA-19 MHS when it meets this threshold) are assembled with the data products listed in the table below. The current dataset spans the period between 8 March 2014 and 31 July 2016. A total of 7102 orbit coincidences occurred within this time span, but since CloudSat only operates on the daytime orbit, this cuts that number by approximately one-half. The next version will include CloudSat snow and rain profile products, and various DPR rain, sigma0 and PIA products, as requested by PMM and CloudSat investigators. Coincidence files are in HDF5 (< 40GB entire dataset), with quick-look graphics. Acknowledgments to Erich Stocker (PPS) for hosting as a GPM product and Phil Partain (CSU) for timely CloudSat data processing.

https://storm.pps.eosdis.nasa.gov/storm (Search for 2BCSATGPM)

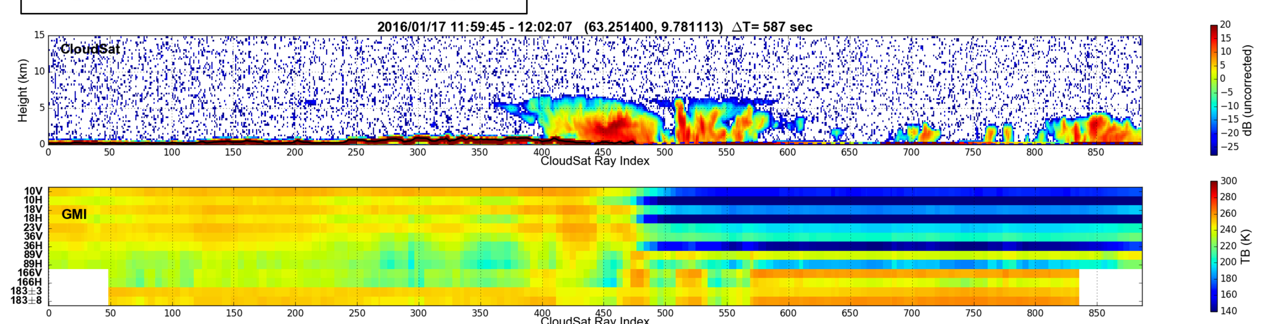
Dataset Name	Satellite	Description	Date Available
2A.GPM.DPR	GPM	DPR Ku and Ka-band radar reflectivity profile and radar-based precipitation retrievals, Version 04A	2014/03/08-current
1B.GPM.GMI	GPM	GMI Level 1B brightness temperatures, Version 04A	2014/03/05-current
2B-GEOPROF	CloudSat	CloudSat vertical reflectivity profile	2006/06/15-2016/07/31 Daylight-only operations since January 2012.
ECMWF-AUX	CloudSat	ECMWF forecast analysis interpolated to each vertical CloudSat bin	2006/06/15-2016/07/31
1C.NOAA18.MHS	NOAA-18	MHS Level 1C intercalibrated brightness temperatures	2006/06/15-2016/07/31
2C-SNOW-PROFILE	CloudSat	Snow water and snow rate profile at each vertical CloudSat bin	2006/06/15-2016/07/31



17 Jan 2016 1201 UTC Coast of Norway



CloudSat under GMI swath



Estimating Non-Raining Surface Parameters to Assist GPM Constellation Radiometer-Based Precipitation Techniques

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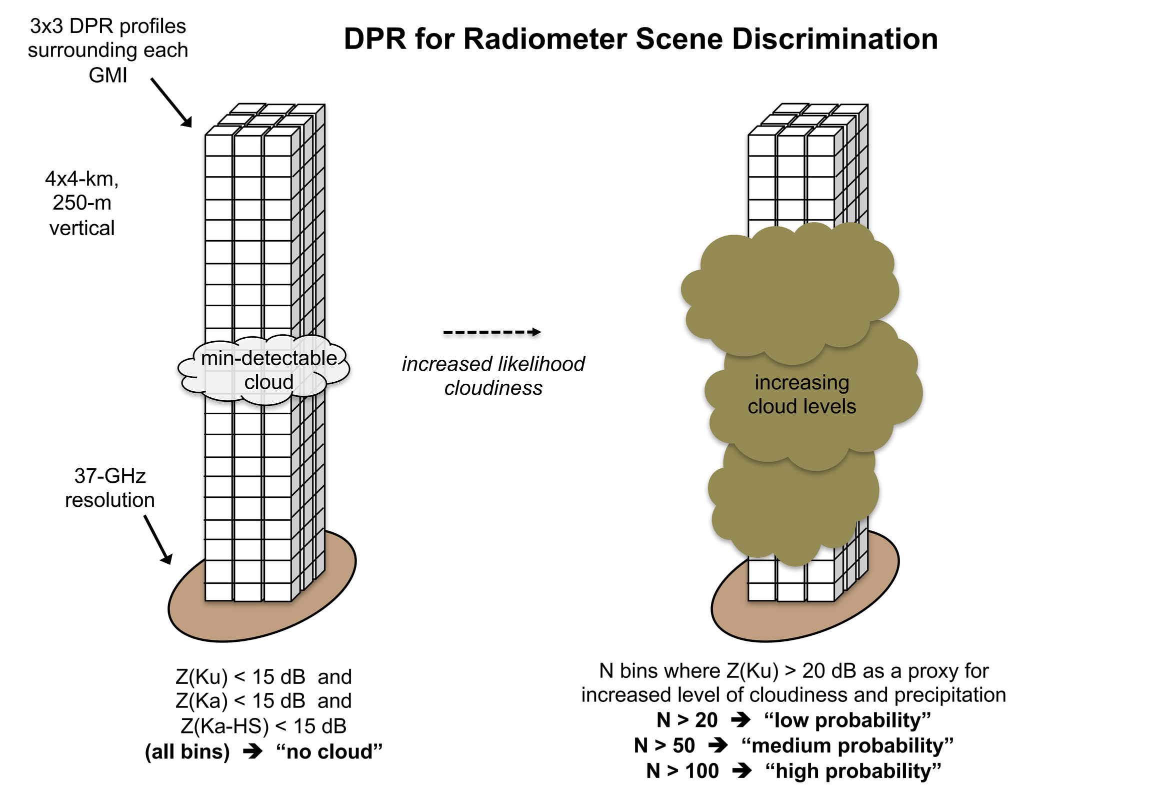
Summary

One of the key challenges for GPM is how to link the information from the single DPR across all passive MW sensors in the constellation, to produce a globally consistent precipitation product. Currently, the surface and environmental conditions at the satellite observation time are interpolated from one or more global forecast models and a surface emissivity climatology, and used for radiative transfer simulations and cataloging/indexing the brightness temperature (TB) observations and simulations, within a common MW precipitation retrieval framework. Since the constellation MW radiometers routinely observe many more non-precipitating conditions than precipitating, here the information content within the non-precipitating GMI observations is studied as a means to characterize the emissivity state and to dynamically track the associated environmental conditions, regardless of underlying surface type.

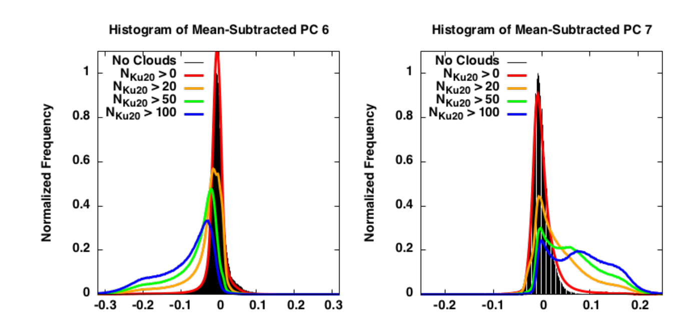


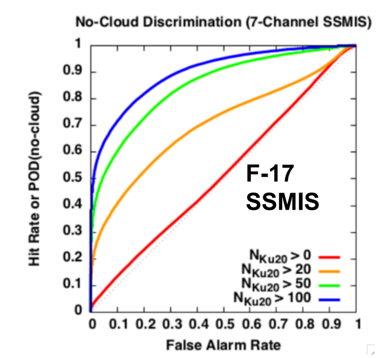
While not a cloud radar, the three DPR radars are used to separate "no-cloud" scenes from "low", "medium" and "high" probability of cloudiness (not necessarily rain).

The method relies upon a nonlinear transformation of TB into emissivity principal component (PC) space, to probabilistically separate "no-cloud" and increasingly cloudy scenes (*Turk et. al.*, JTech, 2016). Transforming each TB observation into PC space, the GPM radiometer a-priori databases are searched globally (indexed into non-equal spaced bins according to the histogram of each PC, for computational efficiency) and inversely weighted in PC distance. The method appears to identify "self-similar" surface locations from the TB observations, without requiring any knowledge of geographical location, surface or environmental/temperature conditions. As the precipitation develops, the PC structure shifts from its "no-cloud" state, shifting and widening the database search region, from which the PDF of rain is obtained and the probability of precipitation.

Cloud/No-Cloud Separation N(Ku) > 20 dB in column
N>0 N>20 N>50 N>100

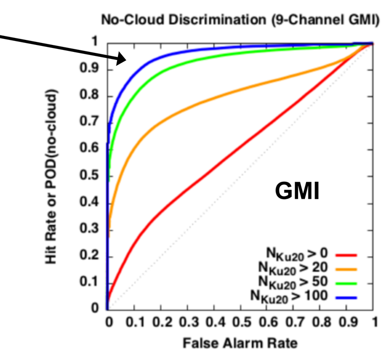
As more DPR cloud bins are present within the GMI radiometer scene, the PC structure shifts from the "no-cloud" range (PC6-7 shown at right). As the cloud level further increases, the a-priori database search moves towards PC domains where more precipitating profiles are present.

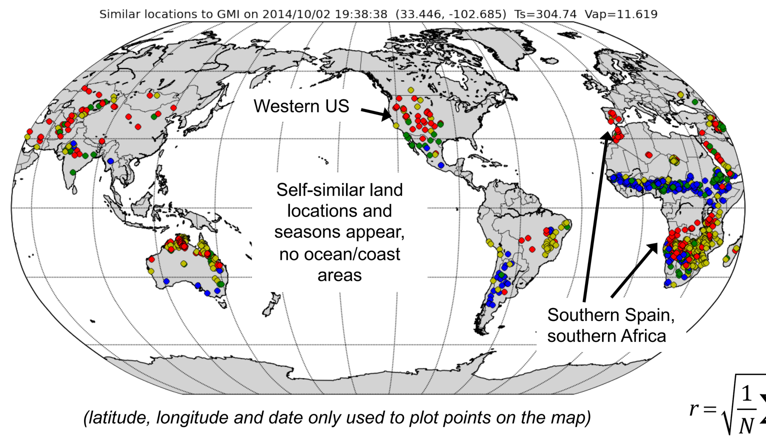




Relative operating characteristic (ROC) curve moves closer to upper left hand corner than for SSMIS

Extension to SSMIS: Heritage 7-channel (no 10 GHz) radiometers such as SSMI and SSMIS do not have the same level of separation as a 9-channel (GMI); the raining and non-raining radiometer scenes will have more "overlap".





(latitude, longitude and date only used to plot points on the map)

West Texas, bare soil 2 October 2014

T_{vap}= 11.6 T_{sfc}=304.7

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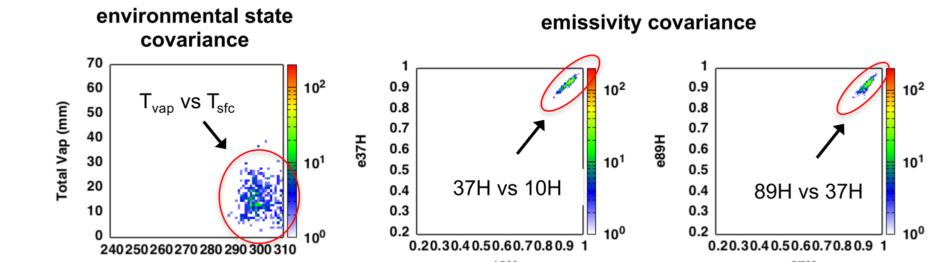
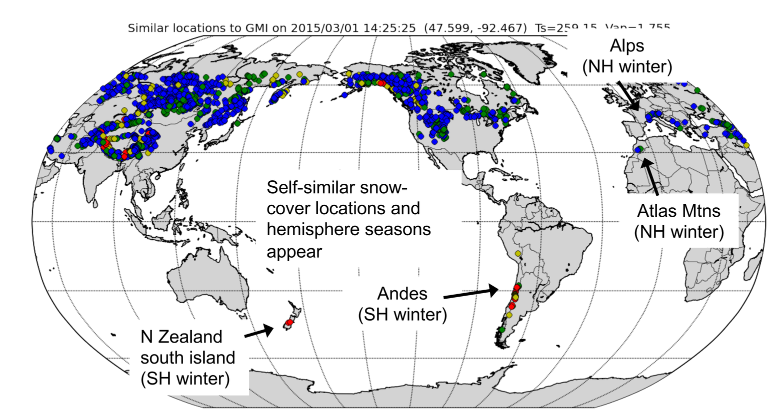
Search GPM database for nearby entries in leading PC-space:

$$r = \sqrt{\frac{1}{N}\sum[(u^{obs} - u_i^{sim})/\sigma_i]^2} \quad N = 3$$





Minnesota, snow-cover 1 March 2015

T_{vap}=1.8 T_{sfc}= 259.1

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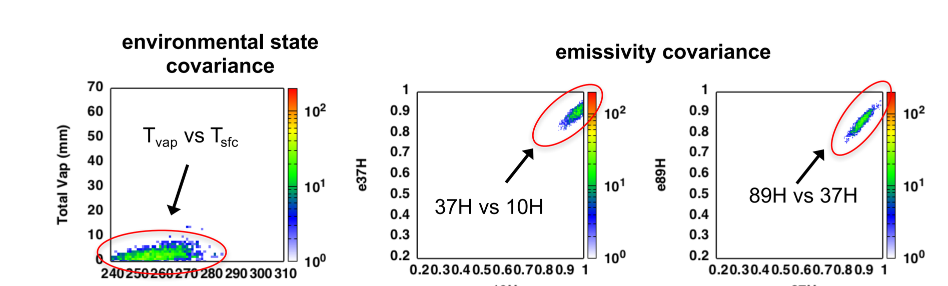

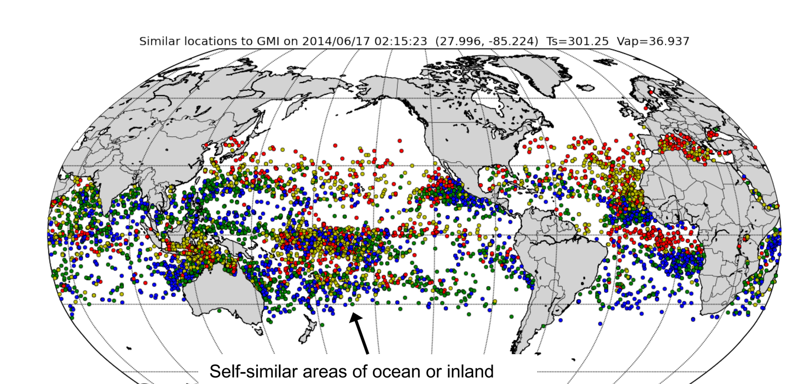

Gulf of Mexico, ocean 17 June 2014

T_{vap}= 36.9 T_{sfc}= 301.2

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